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Monitoring Breast Milk Contamination to Detect Hazards from Waste Disposal

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Human milk is a repository for certain classes of long-lived, fat-soluble environmental contaminant chemicals. Some members of this class, such as the chlorinated pesticides and the chlorinated biphenyls, can be expected to be present at chemical waste disposal sites. Analysis of samples of breast milk obtained from women near such a site could provide documentation that exposure has taken place. However, background contamination is present and must be dealt with by the collection of comparison samples. Sample collection can be difficult because of the low level of chemicals being sought, and thus the possibility of sample contamination. The diagnostic and public health consequences of contaminated breast milk are not clear at this time, and thus chemical analysis of milk should be carried out in a research setting. Despite these difficulties, breast milk monitoring has been a successful tool in certain investigations of the spread of environmental chemicals.

Introduction

Uncontrolled and unquantified exposure of the public to hazardous substances is a consequence of the large amounts made, used, and discarded. The disposal process in particular presents opportunities for exposure during handling and transport, and from chemicals present in poorly operated storage or disposal facilities. Knowing what to do following an accidental exposure requires information on the extent and degree of exposure, any illness that may be attributable to the exposure, and who, if anyone, needs clinical study in greater detail. The chemical analysis of human milk yields data that may be useful during initial investigation or subsequent followup.

Some of the chemicals involved may be suspected of being able to contaminate milk either because they are known to have done so in the past or because they share physical or chemical properties with those that have done so. When this is the case, analysis of milk may seem appropriate for two general reasons. One is that breast milk is an easily collected fluid whose degree of contamination can serve as an index of exposure. The other is that milk is of interest in its own right because of its role as food for children. Analysis of milk has been proposed often enough that an investigation of its usefulness seems called for.

What follows is an outline of some scientific and practical aspects of breast milk analysis, and an examination of some of the assumptions that must be made from a public health and scientific point of view. The issues to be discussed are: (1) the decision that milk analysis is appropriate, (2) dealing with the existence of background contaminant levels, (3) some practical problems in the collection of samples and (4) clinical and public health implications of the data obtained.

Decision to Analyze Milk

Chemicals like DDT and the polychlorinated biphenyls (PCBs), as well as many other high-boiling halogenated polycyclic hydrocarbons, have properties that favor their appearance in breast milk, even when exposures have been to low, unnoticed amounts. The chemicals cannot be excreted or metabolized once they are absorbed and are stored in the body's fat. We expect that the concentration of these chemicals in body tissues is

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directly related to the amount of fat in the tissue. While these chemicals could be measured in fatty tissue (about 65% fat), it is not easily accessible. Since breast milk is about 3% fat, sensitive analytic methods can detect residue levels of these chemicals there. Blood and urine, which are easily accessible, have much lower amounts of fat. Thus, an analytic method that works satisfactorily at the range of concentrations found in milk may be inapplicable at the lower concentrations of blood and urine. Background levels of these kinds of compounds tend to be in a range where, with current technology, milk levels can be determined with success, but blood and urine levels may be too low to detect or very hard to quantify. Since accidental exposures will increase levels above background, analysis of milk in such a situation may provide quantitative data when analyses of other body fluids do not. If preliminary data indicate that exposures have occurred at high enough levels, analysis of blood or urine should be considered since samples will be available from more people. Some statistical aspects of the blood versus fat choice have been treated elsewhere (*1*).

Whether analysis of breast milk is appropriate depends not only on the kinds of chemicals involved in a particular incident and the levels at which they occur; it also depends on the purpose of the study. There are at least four purposes for which analysis has been proposed or used. One is detection of exposure or documentation that it has taken place. A second is epidemiologic study, in which levels of chemicals are to be the index of exposure to the mother or child. A third is diagnostic use, in which some illness in the mother or child may be attributed to the chemical, depending on the level found. A fourth is advisory use, in which the mother is aided in her decision about breast feeding by knowing what level she has.

Documentation of Exposure

For detection of exposure or documentation that it has taken place, the usefulness of breast milk analysis will depend on whether there are sufficient lactating women located appropriately, whether the match between level of exposure and analytic sensitivity works out well, and whether other factors, such as age, are important for the study. For example, the Michigan Health Department used breast milk analysis to estimate the statewide distribution of contamination with polybrominated biphenyls (PBBs) (*2*). Since the sampling frame, the state population, was very large, the availability of adequate numbers of nursing mothers was assured. It was known from previously collected paired blood and fat samples that blood values could be undetectable when moderate amounts of PBBs were demonstrable in fat (*1*). Analysis of milks collected from a statewide probability sample showed that about 90% of lactating women (and inferentially of the whole population) from the lower peninsula had detectable levels. Presumably, a serum survey would have given a falsely low estimate. Thus, the added sensitivity afforded the analytic chemist by the amount of fat in milk was useful for this problem. On the other hand, in Triana, AL, a community with exceptional exposure to DDT (*3*), all 499 sampled residents had detectable serum levels, and a striking increase of level with age was noted. Because of the small population and the high chronic exposures, serum analyses were adequate and breast milk analysis would not have been very informative. Only a few milk samples would be expected and, of course, none would have come from older women.

Epidemiologic Study

The use of breast milk for epidemiologic study of the women who supply the samples is generally done only when some aspect of lactation or the determinants of the levels themselves (e.g., diet, race, age) are under study. Whether hypotheses about illnesses in children exposed via contaminated breast milk may be tested depends mostly on the number of such children available for study. Evaluation of subtle decrements in growth and development, for example, requires large numbers. However, in most exposure situations, children who are *in utero* or breast feeding at the time of exposure should be evaluated as thoroughly as possible. Such children may be particularly likely to display toxicity because of their developmental vulnerability. In the extreme case, one affected child can be informative. For example, Bagnell (*4*) noted cholestatic jaundice in a breast-fed 6-week-old whose mother lunched daily at the family dry-cleaning shop. Trichlorethylene, which was present in the shop, was present in her milk; other causes were ruled out, and the jaundice resolved with cessation of breast feeding.

For other nonlactation studies, breast milk analysis is not likely to prove useful. Lactating women come from a fairly narrow age range, they are generally quite healthy, and in many other ways they fail to represent any broader population. Besides, in any given study, women who find the process of giving samples tolerable are a further subset of lactating women. For example, we are doing a study in North Carolina of the effects of PCBs and DDT in breast milk on the health of breast-fed children; the women who volunteered for this study are a select group. For instance, only 5.5% of the volunteers are black (in a state which is 21.5% black), 54% have 16 or more years of education, and 81% are employed. Because of the very unrepresentative nature of such groups, the choice among biologic fluids for analysis in most nonlactation studies will be blood, fat or urine; breast milk analysis may be a useful "add-on" but will generally be secondary to the main thrust.

Diagnostic or Advisory Use

The diagnostic or advisory use of breast milk analysis is controversial at this time and should not be undertaken outside a research setting. For many chemicals, there is some evidence that laboratories vary substantially within themselves and among each other on the values obtained for a given sample. There is no nationwide quality assurance program as there is for, say, blood lead testing. A more serious objection is that there is neither general agreement nor available data on what level, if any, constitutes a hazard for any of these chemicals. Thus, data should be collected only when they are to be evaluated in a formal way, preferably by formal hypothesis testing. Analysis of milk outside this context does not provide the mother or her physician with any useful information, despite the formidable persuasive powers of an actual number, computer generated. Even in a research setting, these data can be problematic; this point is discussed below.

Dealing with Background Levels

There is now a substantial literature, dating back to 1951 (*5*), showing that it is unusual to find uncontaminated milk anywhere in the world. The data include a series of studies reviewed in 1980 (*6*), 1975 data from EPA on over 1000 United States women (*7*), 1977-78 data from Michigan (*8*), and our North Carolina data. The chemicals usually reported include DDT and its metabolites, PCBs, dieldrin, chlordane and heptachlor. Lindane (BHC, benzene hexachloride) is occasionally reported (*9*); PBBs have been reported from Michigan (*2*). Mirex has been sought but not reliably identified (*7*). There are no obvious secular trends in these data; there is substantial geographic variation in the United States, with the southeast tending to be higher than the northwest (*7*). The widespread prevalence of such contamination has direct implications when the testing of milk is proposed. When exposure to a point source is to be evaluated, overlap of the suspect chemicals with background is to be expected. Thus, control samples must be analyzed simultaneously. When an entire geographic area has been affected (a common situation in waste dump incidents), finding suitable controls is not easy.

Although each individual chemical will be somewhat different, the magnitude of the background problem can be illustrated by considering PCBs as an example. When planning to analyze, a convenient but arbitrary rule of thumb is to try to detect levels of twice background. Our data show a median level of 1.9 ppm milk fat; recent data from Michigan (*8*) show a median level of 1.4 ppm. The average adult female is about 60 kg and about 20% fat; thus in steady state, she has 12 kg of fat containing 17–23 mg PCBs. She can double her body burden, and thus double the level in her milk, by exposure to air, water, soil, food, etc., contaminated by PCBs. PCBs have quite a low vapor pressure, so the notion that 20 mg can be absorbed from the air in the short term is unlikely. Foodstuffs not produced in the area are likely to have quite low levels or be uncontaminated; however, locally raised produce or livestock can be important, as in Michigan (*10*). Water contamination is typically in the low parts per billion range (*11*) because of the low water solubility of the compounds, and thus it would contribute to body burden at a microgram/liter rate. Again, this is relatively unimportant in the short run. However, if the suspect site does pollute local water and fish are taken and consumed, substantial contributions can be made. Fish living in water chronically polluted by PCBs will bioaccumulate the chemicals and levels can reach 5 ppm or more (*12*). A woman consuming quite moderate amounts of such fish could absorb 20 mg easily. Another likely source of contamination is direct contact with the chemical itself or with heavily contaminated dirt from the site. Soil at an uncontrolled site might reach 50–500 ppm PCBs or more. PCBs, like the cyclodiene pesticides and many solvents, can be dermally absorbed; besides, even adults engage in some hand-to-mouth activity, and so small amounts might be ingested. There would be 20 mg in about 40 g of material contaminated at 500 ppm; over a few months, clothes, shoes, toys, or tires would be able to transport this amount, in addition to whatever contribution blowing dust might make. A consequence of these kinds of exposure routes is that a simple decrease in levels with distance from the site should not be expected. Exposure may well depend more on traffic patterns, the presence of children and their habits of play, the number of people living in a household, and their food preferences, rather than directly on distance from a given source.

Under certain circumstances, it may be possible to distinguish source exposure from background by "fingerprinting." The PCBs are a mixture of variously chlorinated biphenyls. The commercial mixtures, once sold in the United States as Aroclors, had numbers representing the percent chlorine by weight and thus, indirectly, the presence of the higher chlorinated congeners. "Background" PCB chromatograms usually look like something between Aroclors 1254 and 1260; this reflects the differing abilities of the congeners to bioaccumulate. There is some selection in the body for the higher congeners. When the exposure is to a relatively pure commercial grade of PCBs, such as to Aroclor 1260, chromatograms from exposed persons may differ from background both in the amount of chemical present and in the different relative amounts of the congeners.

Collection of Samples

To the analytic chemist who regularly works with residue levels of pesticides, the problem of sample contamination is obvious. Fat-soluble chemicals like DDT and PCBs are in fact ubiquitous, and the amounts being sought are small. Exogenously deposited contaminants from glassware, plasticware, fingers, foils and stoppers seem to be much easier to extract from in and around a sample than are endogenously deposited contaminants. Figure 1*A* shows a gas chromatogram from a collection jar in which pentane was shaken against the dull side of an aluminum foil cap (*13*). The initial spike is the pentane, and the rest is silent. When the procedure is repeated with the shiny side towards the solvent, the multiple peaks shown in Figure 1*B* are recorded; they come off at about where endogenous PCBs or other residues are expected. Sample collection and handling posed several problems for us in our field work. For example, efficient collection of the 30 ml or so of milk that we require for analysis meant the use of a breast pump for many women. Hand expression is relatively less efficient and tedious. The pump we chose, as well as many other commercial ones, uses a plastic nipple shield and tubing to avoid loss of the white blood cells in the milk; these are thought to aid in the immune function of the child, and they tend to stick to glass surfaces. We found that the plastic was an unacceptably high source of (presumably) adsorbed contaminants. Finally, we had hand-blown nipple shields and custom tubing made. Because of problems like these that arise from unexpected sources, we recommend that any collection procedure used be documented contaminant-free during actual field operations.

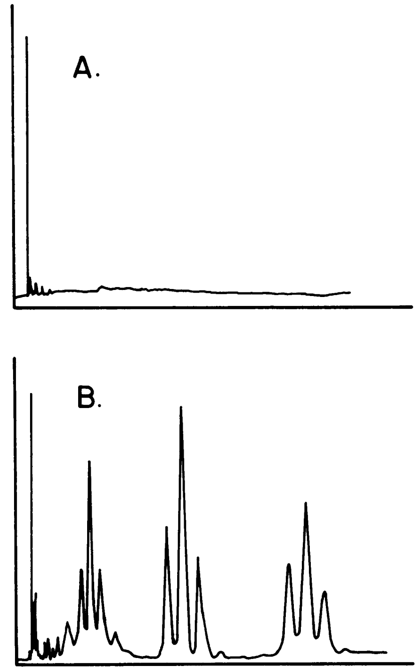

FIGURE 1. GLC of solvent extraction from 2 cm^2 of aluminum foil: (*A*) dull side; (*B*) shiny side. Figure from Albro (*13*), used by permission of the New York Academy of Sciences.

Public Health Implications

Breast milk is usually collected from women who plan to feed their children with it, although sometimes milk can be collected from milk banks and the like. Such women will have a stake in the results of any chemical analysis performed, and the question will arise as to whether the child should continue to breast feed. There is no body of experimental or observational data available from which to counsel mothers in this situation. In the setting of a protective clinical study such as we are doing in North Carolina, we explain that the analytic data are generated for research purposes only, that we will continue to examine the child, and that no illnesses occurring in breast-fed children have as yet been attributed to population levels of PCBs or DDT. In a situation where such rapport will not be developed, very careful thought should be given in advance as to exactly what mothers will be told the levels mean. If private physicians are to be involved in the interpretation of numbers, they must be warned of this in advance. The simple availability of a physician to the project is not sufficient, in our experience, to deal adequately with the concerns that are generated. If these are not dealt with, the potential for jeopardizing subject cooperation with whatever investigation is underway is very high. The use of advisory levels or action levels borrowed from the food regulatory activity of the Food and Drug Administration or the advisory activity of the World Health Organization is problematic, since, for some chemicals, 30–50% of human milk samples will be expected to exceed such levels on the basis of background contamination alone (*6*). The recommendation not to breast feed implies that a benefit will be achieved by stopping that is greater than that usually attributed to breast feeding. In terms of morbidity and mortality decrements in industrialized countries, this benefit due to breast feeding may be regarded as slight, but it appears to be real (*4*) and must be taken into account when recommendations are contemplated.

Summary

Breast milk is a readily collectible and convenient source of human fat, which in turn is a repository for a variety of chemicals to which exposure may occur from contact with hazardous waste. Moderately sensitive and specific methods for breast milk testing exist at a number of laboratories. In appropriate circumstances, analysis of breast milk can give information on the extent to which contamination has spread, and to a lesser degree on the quantity experienced by individuals; however, each incident must be evaluated to decide whether testing of milk will be informative. Background contamination will always be a problem, and data for comparison must be simultaneously available except in extraordinary circumstances. Careful collection procedures must be used when testing for chemicals present at the low levels usually resulting from waste dump contamination. Finally, careful thought must be given to the impact of milk testing on lactating women.

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